



Internally-cured concrete being cast in a bridge deck, Monroe County, Indiana.

508: The photograph shows internally cured concrete being cast in a bridge deck Monroe County, Indiana.

Improving Concrete Bridge Decks with Internal Curing

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DESCRIPTION

Transportation agencies strive to provide durable, long lasting concrete bridge decks. Internal curing is one method that has been developed to design concrete to be less prone to early-age cracking.

KEYWORDS

bridges, concrete, concrete curing, cracks, curing, decks, durability, internal curing, lightweight concrete, permeability, shrinkage

TEASER

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FULL ARTICLE

Transportation agencies strive to provide durable, long lasting concrete bridge decks. While high performance concrete is frequently desired due to its resistance to chloride ingress and corrosion, these mixtures are often accompanied with an increased risk of early age cracking due to the use of high cementitious contents, low water-to-cement ratios, and finer particle sizes. In fact it is often said that the 'high performance concrete' produced is durable, but only between the cracks. Internal curing is one method that has been developed to design concrete to be less prone to early-age cracking. Internal curing also reduces the rate of chloride (or fluid) ingress which can lead to corrosion. The fluid transport properties are reduced in three ways. First, internal curing supplies additional water that promotes increased hydration thereby reducing the porosity of the concrete. Second, internal curing reduces influence of the interfacial transition zone causing it to be 'almost nonexistent' at the lightweight aggregate (LWA) when compared with the interfacial transition zone around sand. Third, internal curing reduces unwanted cracking thereby reducing other paths for fluids to reach the reinforcing steel.

What is Internal Curing

Simply stated, the basic principle is to use prewetted fine LWA to provide moisture to the hydrating cement after the concrete sets. This prewetted LWA is used in place of a fraction of the conventional sand used in a mixture. While the water remains primarily in the prewetted LWA during mixing and transportation, the water can be drawn out of the

LWA due to pressure that is developed in the pore fluid (e.g., 'water' in the concrete) after setting, or prior to setting in the case of evaporation. In the latter case, the prewetted LWA will assist in reducing plastic shrinkage, settlement, and its associated cracking.

This concept of internal curing is compared and contrasted with more conventional (external) curing in Figure 1. Conventional external curing places water at the surface of the concrete shortly after placement that can be absorbed over time. In practice, water curing is often difficult to perform and as such curing membranes or sealers are often used; however, these approaches do not add additional needed water to the system. Further, in lower water-to-cement ratio systems the external curing water cannot penetrate much beyond the surface (on the order of 3 mm of movement after 18 hours). Internal curing, however, uses the fine LWA to supply water uniformly across the cross section as shown in Figure 1. Proportioning procedures exist to determine the amount of lightweight aggregate to use considering both the volume of water that is to be supplied and the spatial distribution of the LWA.

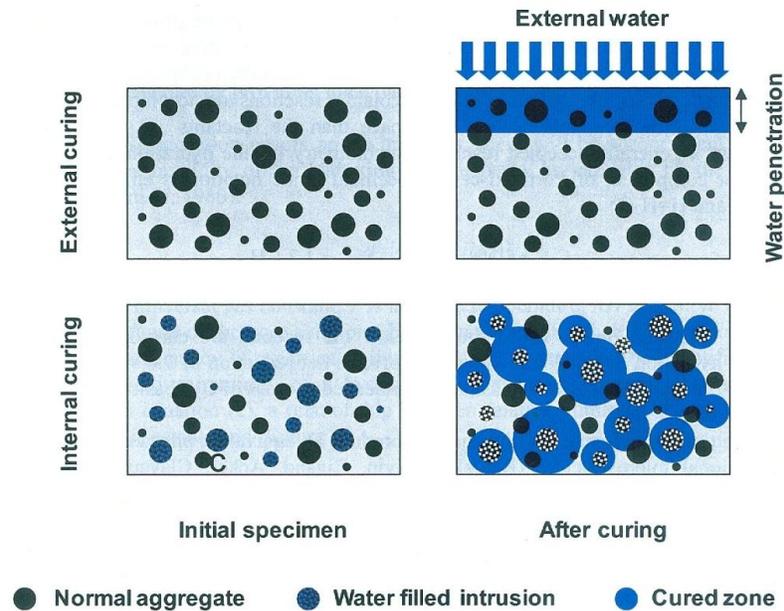


Fig. 1. Illustrating the concept of External and Internal Curing (Castro, 2011).

508: The illustration shows normal aggregate, water-filled intrusions, and cured zones for concrete with internal curing and for concrete with external curing.

A Field Trial in Monroe County Indiana

Following up on a substantial amount of laboratory research that has been performed regarding internal curing, several recent bridge decks have been cast using these materials to transition the technology from the lab to the field. While several bridge decks have recently been cast by the New York State Department of Transportation (NYSDOT), this short article will report some observations from a pair of decks in Monroe County, Indiana (outside Bloomington) that were cast in September 2010. This pair of county bridges was similar in design and location. Both decks were cast using ready mix concrete. The first deck was cast using a conventional bridge deck concrete mixture, while the second was cast using an internally cured bridge deck concrete mixture that was made using the same raw materials. While the exact proportions will vary, the internally cured mixture had approximately 55% of the fine aggregate replaced

with lightweight aggregate. It should be noted that this value will vary depending on the mixture proportions and the properties of the aggregate, however it is given as a point of reference*. The cover photo shows the casting of the internally cured deck where it was noted that the concrete was able to be placed and finished very similarly to the conventional concrete. In fact, it was noted by one finisher that it was less 'sticky' and slightly easier to work with.

While research is underway to quantify the performance of the conventional and internally cured bridge decks, some preliminary observations have been made after the first year. First, while the one-day strength of the internally cured concrete was approximately 10% less than that of the conventional concrete, the conventional and internally cured concrete had equivalent strengths at approximately 10 days. After 3 months, the internally cured concrete was 20% stronger than the conventional concrete. Rapid chloride permeability testing (ASTM C1202) showed that the internally cured concrete had a 10% lower charge passed at 28 days and nearly 40% lower charge passed after 3 months. The internally cured mixture also had a lower shrinkage. Additionally, it was noted that cracks developed in the conventional deck after the first few months of service (Figure 2), while at the time of this article (nearly one year after placement), the internally-cured concrete has no visible cracking (Figure 3). While cracking can occur in bridges for a variety of reasons, the lack of visible cracking in the internally cured deck is consistent with the reduction in the concrete's autogenous and drying shrinkage.

The full report of results from this trial which include a wide range of additional tests will be available in late 2011 from the Indiana Local Technical Assistance Program.



Fig. 2. Cracking that occurred when using a “conventional bridge deck mixture” in Monroe County, Indiana.

508: The photograph shows one longitudinal deck crack that occurred when using a “conventional bridge deck mixture” in Monroe County, Indiana.

References

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Further Information

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Fig. 3. Currently “crack free” internally-cured concrete bridge deck in Monroe County, Indiana after 1 year in service.

508: The photograph shows the “crack free” internally-cured concrete bridge deck in Monroe County, Indiana after 1 year of service.